Breaking Up Tornadoes

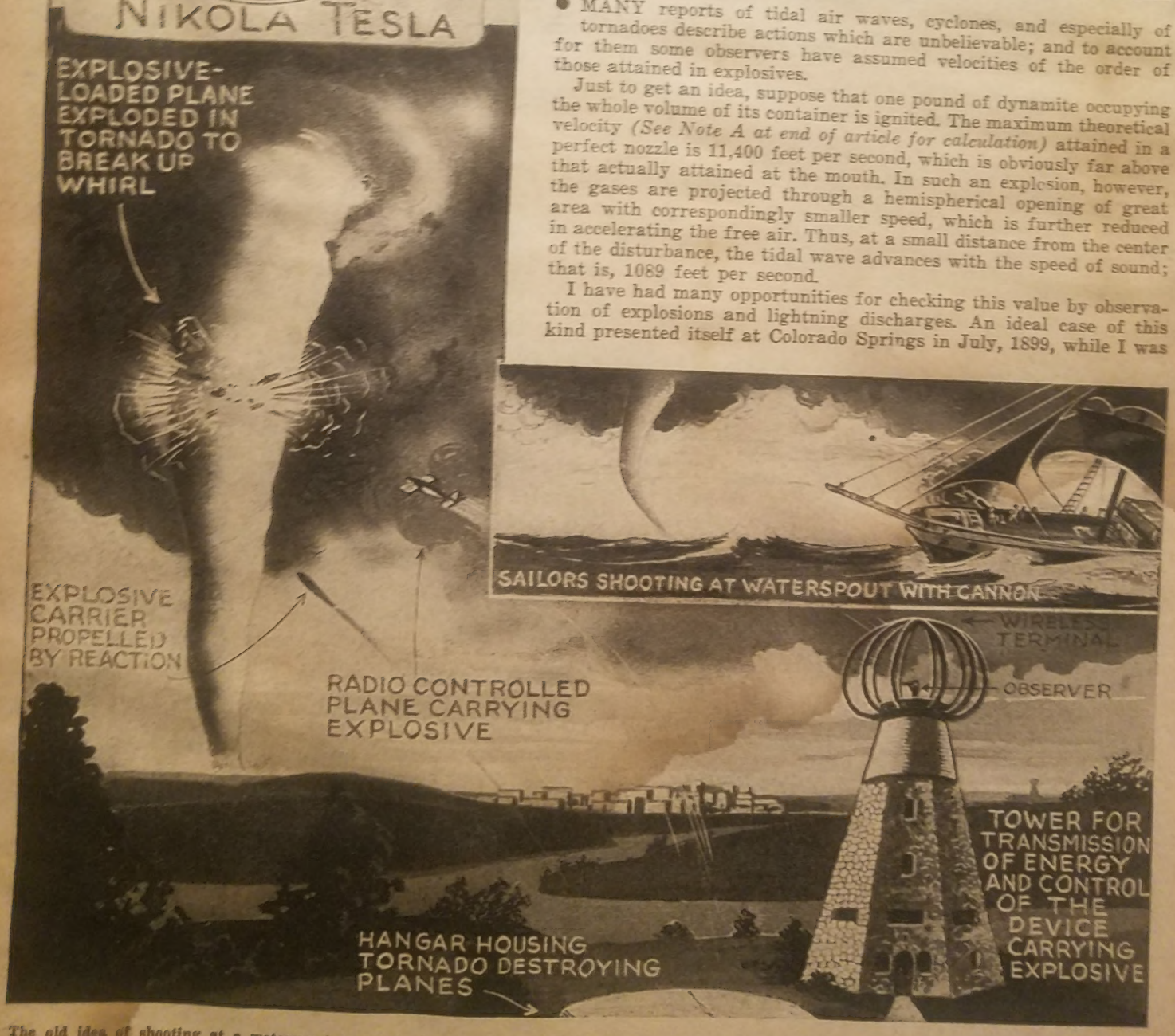
By NIKOLA TESLA

EVERY year whirling tornadoes cause great damage in the United States; and this disaster, like earthquakes, has hitherto been accepted as unavoidable. But the great scientist and inventor, Nikola Tesla, who has given the matter special study, both experimentally and theoretically, here proposes a practicable plan for the organization of a national government service to combat and break up tornadoes, when forming; just as a fire department responds to an alarm and overwhelms the blaze while it is still small. It is to be hoped that this proposal will be met by official investigation and adequate action at Washington.—EDITOR.

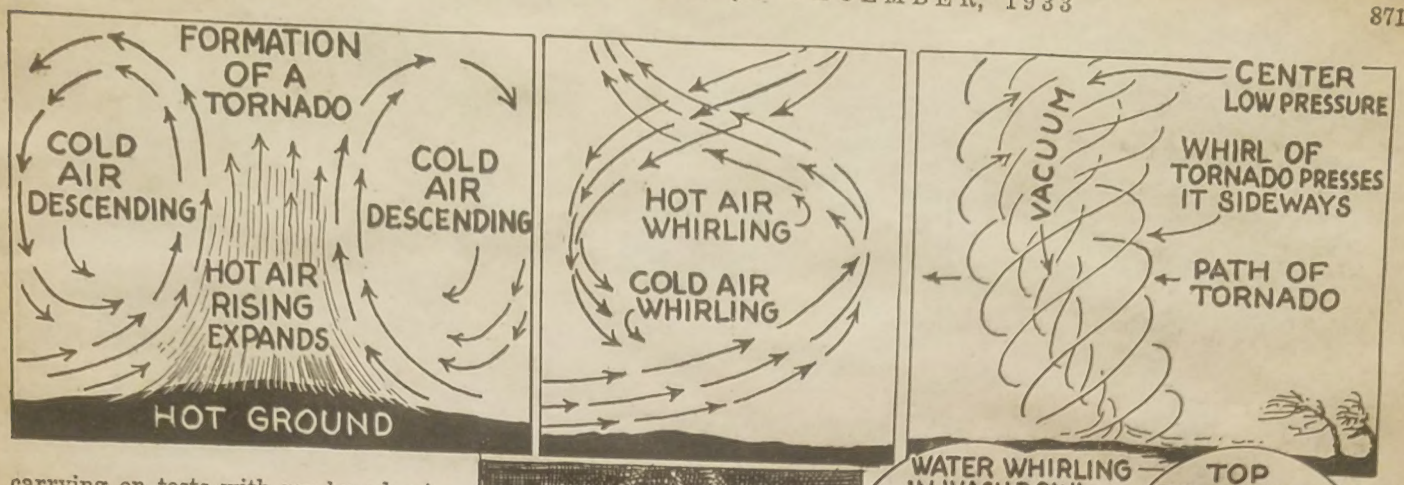
● MANY reports of tidal air waves, cyclones, and especially of tornadoes describe actions which are unbelievable; and to account for them some observers have assumed velocities of the order of those attained in explosives.

Just to get an idea, suppose that one pound of dynamite occupying the whole volume of its container is ignited. The maximum theoretical velocity *(See Note A at end of article for calculation)* attained in a perfect nozzle is 11,400 feet per second, which is obviously far above that actually attained at the mouth. In such an explosion, however, the gases are projected through a hemispherical opening of great area with correspondingly smaller speed, which is further reduced in accelerating the free air. Thus, at a small distance from the center of the disturbance, the tidal wave advances with the speed of sound; that is, 1089 feet per second.

I have had many opportunities for checking this value by observation of explosions and lightning discharges. An ideal case of this kind presented itself at Colorado Springs in July, 1899, while I was



The old idea of shooting at a waterspout was correct in principle, but insufficient in force. Yet, as calculated here, the force of a tornado can be overcome by modern explosives, which might be efficiently and safely applied as shown.



carrying on tests with my broadcasting power station (which was the only wireless plant in existence at that time). A heavy cloud had gathered over Pike's Peak range, and suddenly lightning struck at a point just ten miles away. I timed the flash instantly and, upon making a quick computation, told my assistants that the tidal wave would arrive in 48½ seconds. With exactly the lapse of this time interval, a terrific blow struck the building, which might have been thrown off the foundations had it not been strongly braced. All the windows on the exposed side and a door were demolished, and much damage was done in the interior. Taking into account the energy of the electric discharge and its duration, as well as that of an explosion, I estimated that the concussion was about equivalent to that which might have been produced by the ignition of twelve tons of dynamite. Though the mechanical effects of lightning bolts diminish with the square of the distance, they are still plainly observable within the range of six hundred miles.

It should be borne in mind that these actions are of very small duration, and that a steady gale of such velocity would produce appalling effects. It would quickly erode and grind up the hardest materials, fuse metals by friction and impact and burn up anything that is combustible. Objects, no matter how large and heavy, would be carried off like feathers, and even a mountain range could not resist for any considerable period of time; since

the pressure on an area normal (perpendicular) to the direction of the air blast would be close to three thousand pounds per square foot. Certainly, the inhabitants of this globe have reasons to congratulate themselves that such storms are impossible. Tornadoes, such as actually occur, are bad enough.

The fact is that relatively very small velocities of the wind are quite capable of producing the actions noted even though they may appear astonishing and puzzling at first thought. To illustrate, consider the mechanical effect of a stalk of dry grass or straw hurled normally against a wooden plank with a speed of only 150 feet per

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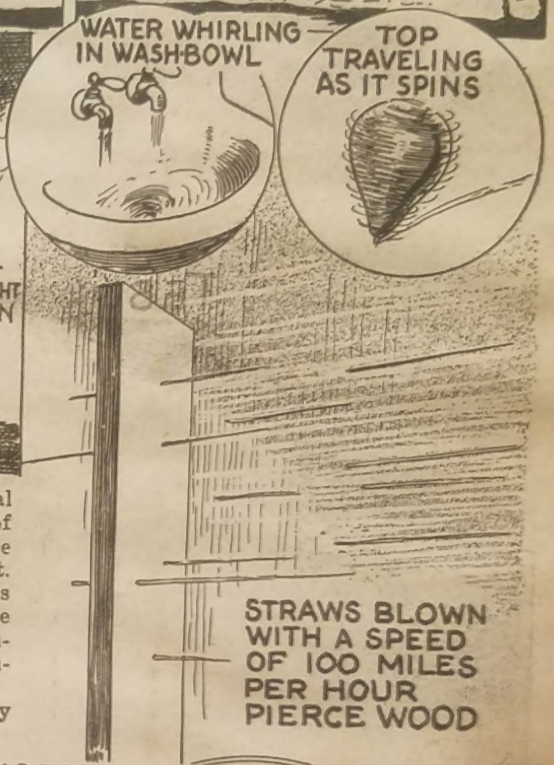

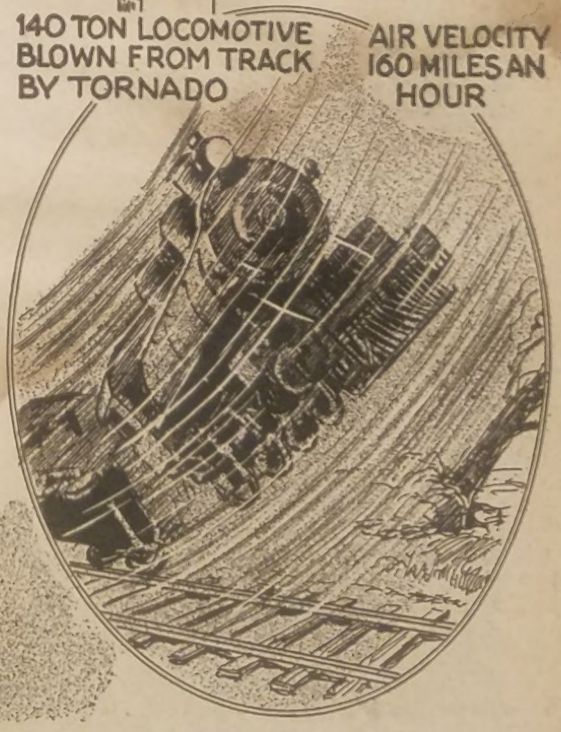

The formation of a tornado is shown above; it spins, as do the waste water and the top. Its tremendous velocity of rotation enables it to accomplish many of the freak results shown; just as when the soft candle is shot undamaged through a hard board.

Breaking Up Tornadoes

(Continued from page 871)

second. (See Note B) The force of 2929.5 pounds per square inch is much more than the plank can withstand; the compressive strength of oak perpendicular to the grain being less than half of that. Evidently, then, an effect of this kind can be surely expected even with much smaller speed, especially if the stalk is pointed.

In this connection it is of interest to mention a classical experiment, which used to be shown to students in some European institutions of learning. It consisted in firing from a gun a tallow or stearin candle at a board 0.4-inch thick. To the amazement of the onlookers, the soft missile not only went through the wood but did not appear much worse for the experience. The secret of success was in the quickness of the transit, not giving enough time for the mass of the candle to yield. The obvious inference from such action is that an exposure to a windstorm is always fraught with danger to life; for bits of flying material, not excluding pieces of straw, may penetrate deeply into the flesh. If my memory serves me right, I have read of serious accidents of this sort.

But the highest air velocities observed in storms are not, in themselves, adequate to explain certain stupendous performances of the wind, such as lifting loaded cars and locomotives and hurling them to great distance. When I first read such reports, many years ago, they afforded me amusement as I took them for original American **canards**, often sprung on unsophisticated foreigners. When I found, to my unspeakable astonishment, that they were substantially true I endeavored again and again to prove them by theories and calculations; but it was only lately that I solved this long-standing riddle.

Whirling movements of the atmosphere have been known and dreaded since time immemorial, but, beyond accounts of their destructive actions, mostly uncertain, little positive information can be found about them. In 1862 was published by H. W. Dove an important work, entitled "The Law of Storms"; dealing chiefly with cyclones, which frequently extend over a large portion of the globe and travel thousands of miles before their energy is spent. These are easily studied and the chief facts concerning them are now well known. Not so the incomparably more dangerous **local storms, the real tornadoes,** which are sudden, erratic, ephemeral (short-lived) and extremely violent manifestations difficult to investigate.

Of late years the U. S. Weather Bureau and the Smithsonian Institution have been supplying data which are reliable and of value in connection with the subject; nevertheless, our knowledge of tornadoes is still fragmentary. Ignoring newspaper reports, which are not quite reliable, and confining myself to facts unmistakably established, I have come to certain conclusions regarding these phenomena, which might be important, and can be summarized as follows:

(1) The maximum velocity of the air forming the funnel probably never exceeds, say, 235 feet per second or about 160 miles an hour; which I think ample to explain all the actions observed. In his "Manual of Meteorology," an exhaustive treatise lately published, Sir William Napier Shaw makes the state-

(Continued on page 920)

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Breaking Up Tornadoes

(Continued from page 905)

ment that speeds of 300 miles per hour or 440 feet per second, and even more, may be attained, which is most unlikely to be the case. It must be borne in mind that an air blast of 150 feet per second readily carries off bricks and other such heavy objects.

(2) Contrary to popular notion, attributing to the tornado immense energy, it has much of the peculiarity of an explosive. Its power is great because of concentration and swiftness of action, but the energy is surprisingly small. Just to give a rough approximation, consider a whirl of an outside diameter of 1200 feet at the top, about the same height, and a diameter of 300 feet at the base (See Note C). The same energy would be developed by the consumption of 1.24 tons of gasolene or 5.74 tons of dynamite. It should be stated, however, that this estimate is by far too high; for the whole funnel is not filled with air of uniform density and not all of it spun at maximum speed.

(3) The tornado whirl is a huge pump, drawing air through the opening at the top and discharging it from the periphery (rim) at the same rate, simultaneously producing rarefaction in the interior. In this respect its action may be likened to that of a multi-staged vacuum pump; for, as the air rushes from the top to the base, more and more of it is drawn to the periphery, increasing progressively the vacuum which may thus attain a high value near the ground. That accounts for the gradual contraction of the whirl. What degree of rarefaction is actually reached in this monstrous contrivance of nature may be roughly estimated when considering that, for any horizontal section of the funnel, the centrifugal force of the air is balanced by the oppositely-directed differential pressure existing between the outside and interior of the whirl. Other things being alike, the centrifugal force is inversely as the **radius of gyration** (average distance of the mass from the center); therefore the contraction of the funnel is, at least, a coarse measure of the rarefaction.

To be explicit, if the diameter close to the ground is one quarter of that near the top, then it may be safely inferred that the vacuum at the base must be about four times higher than in the top region, where there is no appreciable contraction.

As the measured pressure difference in pumps is somewhat greater than that given by the formula (Note D) it is tolerably certain that in the case considered a vacuum of not less than four inches would be attained.

(4) Most of the mechanical effects of a tornado are, as a rule, greatly intensified through water, dust, sand and other objects carried by the blast. Even though these materials may be present in a very small percentage by volume, they are hundreds or thousands of times heavier than the air, and may add enormously to the momentum and impact.

(5) The translatory (from place to place) motion of the funnel is rather across, and not in the direction of the wind, as commonly believed. This is due to its rapid rotation, causing the so-called Bernouilli or Magnus effect, only much more intense. The force pushing it across the wind may be many times greater than that urging it along the same. The whirl is propelled from the side of greater static pressure, where the rotation is against the wind and to-

wards which it leans, in the direction of the opposite side where the reverse condition exists. It is well to remember this in such a storm. If the observer sees a leaning funnel, he is in no immediate danger, but if the funnel appears straight he should run for shelter at once.

It will now be easy to show how a large and very heavy body, such as a loaded railroad car or locomotive, can be lifted by the tornado and transported to considerable distance. American locomotives, which are the biggest in the world, may have a length of 66 and a width of 11½ feet, presenting thus 760 square feet in horizontal projection. At the moment the whirl strikes the vehicle, the wheels, connections and other obstacles under the main body arrest the motion of the air, causing a static pressure of 138 pounds per square foot in excess of that of the atmosphere. But as determined above, owing to the vacuum, a pressure difference of four inches of mercury (that is, two pounds per square inch or 288 pounds per square foot) is maintained, making the whole difference of pressure between the spaces under and above the locomotive 288+138=426 pounds per square foot. The total upward push exerted on the exposed area of 760 square feet is thus 323,760 pounds, which is much more than the weight of such a locomotive (estimated at 280,000 pounds when fully equipped for service).

Ordinarily, the weight should be much smaller; and one can readily see that the vehicle may be instantly raised in a spiral, accelerated and hurled away tangentially to great distance. The average person may be surprised that an insignificant vacuum is sufficient for so stupendous a display of force; but the figures afford an unmistakable proof. I may add that I have assumed minimum values which will be, in all probability, greatly exceeded.

The constant fear of danger from tornadoes and the great losses of life and property which they cause in certain parts make it very desirable to find some means of effectively combating, if not preventing them. Whenever man attempts to interfere with the order of things determined by immutable laws, he finds that his efforts are utterly insignificant when compared with the vast movements of energy in Nature.

One of the greatest possible achievements of the human race would be the control of the precipitation of rain. The sun raises the waters of the ocean and winds carry them to distant regions, where they remain in a state of delicate suspension until a relatively feeble impulse causes them to fall to earth. The terrestrial mechanism operates much like an apparatus releasing great energy through a trigger or priming cap.

If man could perform this relatively trifling work, he could direct the life-giving stream of water wherever he pleased, create lakes and rivers and transform the arid regions of the globe. Many means have been proposed to this end, but only one is operative. **It is lightning, but of a certain kind.**

More than 35 years ago, I undertook the production of these phenomena and, in 1899, I actually succeeded, using a generator of 2,000 horsepower, in obtaining discharges of 18,000,000 volts carrying currents of 1,200 amperes, which were of such power as to be audible at a distance of 13 miles. I also learned how to produce just such lightnings as occur in Nature, and mastered all the technical difficulties in this connection. But I found that even the small

An Interview With Nikola Tesla

By H. WINFIELD SECOR

(*Continued from page 913*)

years has been proceeding at a bewildering pace, the future offers incomparably greater possibilities. Especially bright appear to be the prospects for wireless experts if the art is permitted to expand freely and the enterprises are raised to a higher level and dignity.

The Edison Questionnaire

Q. With especial regard to the Edison questionnaire, do you believe this to be a good way to select an employe? How do you select employes?

A. I regret to state that I cannot agree with Edison. I may say, in fact, that my views are diametrically opposite. A young man with a good college education will always have an overwhelming advantage in working out the problems of his life. Edison attaches too great a value to mere memory. The imitative gift, altho useful, is not of very high order. Some monkeys, for instance, which are possest of but rudimentary intelligence, exhibit it to an astonishing degree. Encyclopedias are now within the reach of every employe and there is no necessity for surcharging the mind with virtually useless knowledge. I prefer to test the worth of an employe by giving him some problems to solve. This involves the exercise of his highest faculties. An assistant who can solve problems is worth a hundred of those who are able to tell what *has been done*. But, perhaps, the best is the method followed by the great J. Pierpont Morgan, who placed character above all and never made a mistake. Character implies intelligence, devotion to the task, loyalty, honesty, good sense, and other qualities which are especially valuable in an associate.

Spiritualism

Q. Do you believe in spiritualism to any degree? Do you really believe that a full life-size materialization of a human body has ever been produced at a spiritualistic séance?

A. Most certainly I do not believe in any such manifestation, but I have no prejudice against anyone who gives himself to these illusions, except those who are cunningly exploiting the public. I have proved to my complete satisfaction, thru continuous observation, that we are automatic engines, the actions of which are governed from the outside chiefly by rays of light. Being of identical construction and subject to the same influences, we respond in like manner. This concordance of action makes possible mutual understanding, and is the basis of what we term "reason." Our minds are blank, there is no stored knowledge, and memory is simply the increased facility of response to repeated impressions. It is like an echo in a forest which only occurs in answer to a call.

Will Radiophone Supplant Present Wire System?

Q. Do you think that radio telephones will supplant the wire telephone in the near future? Do you believe that several hundred thousand radiophone stations could operate in an area no larger than that covered by New York, all using different wave lengths, without troublesome interference?

A. I do not think that the development of the wireless telephone will be hurtful to intelligence transmission thru wires.

Tremendous Possibilities of Radio

An Interview With Nikola Tesla

By J. P. GLASS

[Nikola Tesla, leading authority, electrical wizard and inventor, discoverer of alternating currents, power transmission and induction motor, system of arc lighting, system of electrical conversion and distribution by oscillatory discharges, generators of high frequency currents, transmission of energy through a single wire without returns, the Tesla coil or transformer, Tesla turbine, etc., has been studying the possibilities of wireless transmission of power since 1884. Dr. Tesla sleeps but two hours out of the twenty-four and eats only two light meals a day. Tall and gaunt, almost totally withdrawn from distractions that interfere with his work, his being seems fairly to burn with his intense purpose.

Dr. Tesla is an extremely hard man to approach as he is wrapped up in his work. Mr. Glass was able to arrange with Dr. Tesla to dictate answers to written questions, which makes the following of a direct report than the usual article. Most extremely important and interesting material more men, whose imaginations have been stimulated by the keen radio interest that has gripped the country have no doubt felt that they would like to ask a great expert some of the questions that are answered in this timely article.—EDITOR.]

HERE, briefly, is an outline of the future of wireless transmission, as viewed by Nikola Tesla, the great authority. Dr. Tesla, who began his electrical investigations as far back as 1884, and has been steadily pushing them through the intervening thirty-eight years, does not expect great changes in the physical aspects of life as we know it in modern cities and closely settled communities. For such, the transformations wrought will be chiefly social in their nature, the beneficent results of increased communication and wider spread education. Mankind will be brought closer together, the dissemination of knowledge will be greatly multiplied, and a complete understanding is bound to result.

Business will be affected in the sense that its means of operation will be given increased facility and it will be afforded new avenues of endeavor. But life will move forward with little variation, with largely the same methods of living, occupation, transportation and amusement.

However, this will not be true of those portions of the earth now regarded as inaccessible. "Transportation of electrical energy in unlimited amounts to any point in the world" means that the desert will be made to bloom and the mountain range robbed of its bleakness.

Man, equipped with power and light and means of oral and visual communication, can penetrate to the most unfrequented places and speedily build for himself communities with all the advantages of the metropolitan centers. Railroads will not be necessary because airships and airplanes, availing themselves of the same energy which man will apply to the development of the earth, will afford him transit wherever he may wish to go.

To gain time and to insure accuracy, the interviewer submitted a number of questions to Tesla in writing. His replies were dictated. It is possible, therefore, to present what amounts to a stenographic report of the interview, as follows:

Question: Have you made any discoveries in connection with the wireless principle which have not been given to the public and, if so, would you care to state them?

MR. TESLA: I am glad to say I have, although I am not prepared to discuss them at present in a general way.

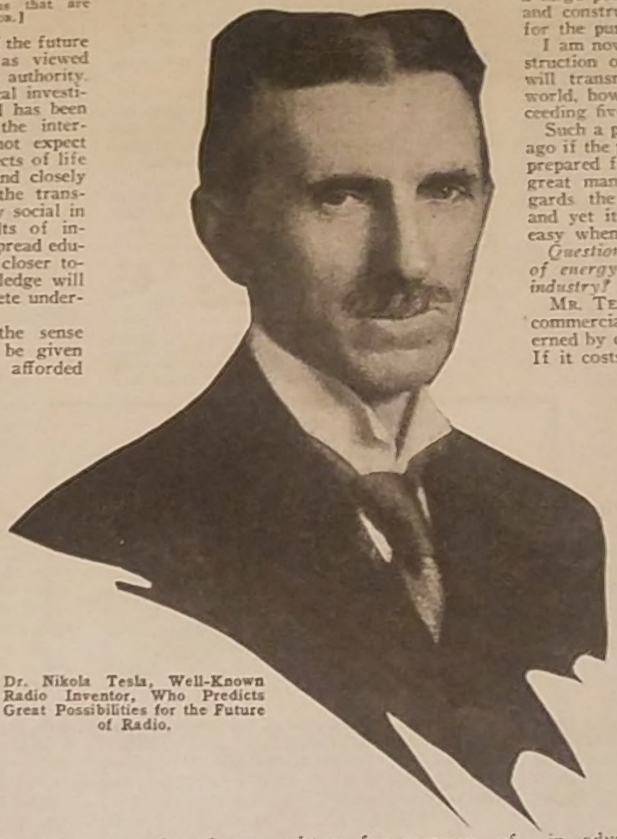
One of these inventions will enable us to condense the wireless transmitting apparatus to such an extent that the entire plant for carrying the human voice around the globe will be contained in a smaller space than that occupied by a little cottage. There will be no high towers.

In this connection I have made a discovery as interesting as it is important, which, when it is announced, will cause great surprise among engineers. This cannot be disclosed, now.

A number of other inventions relate to the control of the energy by delicate means, isolation of impulses, and their reception and recording at distance.

Question: What will be the effect of these inventions upon the wireless art?

MR. TESLA: I think that they will greatly facilitate wireless transmission in several ways. The transmitting apparatus will be very much cheaper and qualitatively superior by far to existing types. Especially in the use of such transmitters for purposes of broadcasting will great advantages be secured. The receivers will be much more responsive, too, and sharply differentiative. This means, of course, that more instruments can be operated simultaneously without interference and at greater distances.



Dr. Nikola Tesla, Well-Known Radio Inventor, Who Predicts Great Possibilities for the Future of Radio.

The compactness of the transmitter will greatly facilitate its installment, so much so, indeed, that I look confidently to the time when all leading newspapers and large institutions of business will possess equipment enabling them to communicate with any part of the world.

Newspapers, for instance, could maintain their own transmission plants, which could be used not merely for broadcasting news bulletins as an auxiliary service to their printed editions, but for gathering reports from their correspondents; and business concerns could have their own private systems by which they could have direct communication with their agents and customers everywhere.

Question: You have established the fact that electrical energy can be transmitted without wires—how soon will it be possible to carry on such transmission on an industrial scale?

MR. TESLA: I have been confident, ever since I gave the outline of my wireless system in scientific lectures delivered in 1893, that power could be transmitted without wires, and that ultimately we would establish plants for such transmission on an industrial scale. But it was not until 1899 that I obtained absolute experimental evidence that this could be done in a manner far more perfect than I had dreamed of before. Ever since that time I have devoted a large portion of my energy to the design and construction of the devices to be used for the purpose.

I am now prepared to undertake the construction of a wireless power plant which will transmit energy to any point in the world, however distant, with a loss not exceeding five per cent.

Such a plant would have been erected long ago if the profession (engineering) had been prepared for it. But, as a matter of fact, a great many engineers are in doubt as regards the possibility of this achievement, and yet it is as with everything else, very easy when you know how.

Question: How will wireless transmission of energy affect the present machinery of industry?

MR. TESLA: It must be remembered that commercial enterprises always will be governed by economic principles. To illustrate: If it costs less to propel an airship by fuel than it would if wireless energy were employed, then fuel will be used and wireless energy will be looked upon as a luxury.

The history of invention proves that new developments always take place along the lines of least resistance and that invariably time is given for the adjustment of existing conditions.

I have studied the subject deeply for many years and believe that the chief future of wireless power, for some time, at least, lies in the use of small quantities of energy in places which are inaccessible. I should think that an advance of this character can only be helpful, then, in the development of all branches of industry.

But, if my plans mature and turn out as I hope, aerial navigation will take enormous strides in advance, for it will be possible for the machines to be operated without carrying stored energy, which limits their cruising radius. It stands to reason that their carrying capacity and speed will be increased when wireless power becomes available. Of the two types of aircraft, the heavier-than-air and dirigible balloon, the latter will be more suitable for this new method of propulsion.

In certain other fields wireless transmission undoubtedly will prove revolutionary. For instance, when it is desired to light an isolated dwelling, more or less remote from centralized communities, this method will prove ideal, for a house can be equipped with a small and very compact apparatus at a ridiculously moderate price.

Suppose, too, that a man goes to the Adirondacks on a camping expedition. He supplies himself with the necessary receiving

(*Continued on page 940*)

Tremendous Possibilities of Radio

An Interview With Nikola Tesla

By J. P. GLASS

[Nikola Tesla, leading authority, electrical wizard and inventor, discoverer of alternating current, power transmission and induction motor, system of arc lighting, system of electrical conversion and distribution by oscillatory discharges, generators of high frequency currents, transmission of energy through a single wire without return, the Tesla coil or transformer, Tesla turbine, etc., has been studying the possibilities of wireless transmission of power since 1884. Dr. Tesla sleeps but two hours out of the twenty-four and eats only two light meals a day. Tall and gaunt, almost totally withdrawn from distractions that interfere with his work, his being seems fairly to burn with his intense purpose.

Dr. Tesla is an extremely hard man to approach as he is wrapped up in his work. Mr. Glass was able to arrange with Dr. Tesla to dictate answers to written questions, which makes the following extremely important and interesting material more of a direct report than the usual article. Most men whose imaginations have been stimulated by the keen radio interest that has gripped the country have no doubt felt that they would like to ask a great expert some of the questions that are answered in this timely article.—EDITOR.]

HERE, briefly, is an outline of the future of wireless transmission, as viewed by Nikola Tesla, the great authority. Dr. Tesla, who began his electrical investigations as far back as 1884, and has been steadily pushing them through the intervening thirty-eight years, does not expect great changes in the physical aspects of life as we know it in modern cities and closely settled communities. For such, the transformations wrought will be chiefly social in their nature, the beneficent results of increased communication and wider spread education. Mankind will be brought closer together, the dissemination of knowledge will be greatly multiplied, and a complete understanding is bound to result.

Business will be affected in the sense that its means of operation will be given increased facility and it will be afforded new avenues of endeavor. But life will move forward with little variation, with largely the same methods of living, occupation, transportation and amusement.

However, this will not be true of those portions of the earth now regarded as inaccessible. "Transportation of electrical energy in unlimited amounts to any point in the world" means that the desert will be made to bloom and the mountain range robbed of its bleakness.

Man, equipped with power and light and means of oral and visual communication, can penetrate to the most unfrequented places and speedily build for himself communities with all the advantages of the metropolitan centers. Railroads will not be necessary because airships and airplanes, availing themselves of the same energy which man will apply to the development of the earth, will afford him transit wherever he may wish to go.

To gain time and to insure accuracy, the interviewer submitted a number of questions to Tesla in writing. His replies were dictated. It is possible, therefore, to present what amounts to a stenographic report of the interview, as follows:

Question: Have you made any discoveries in connection with the wireless principle which have not been given to the public and, if so, would you care to state them?

MR. TESLA: I am glad to say I have, although I am not prepared to discuss them at present in a general way.

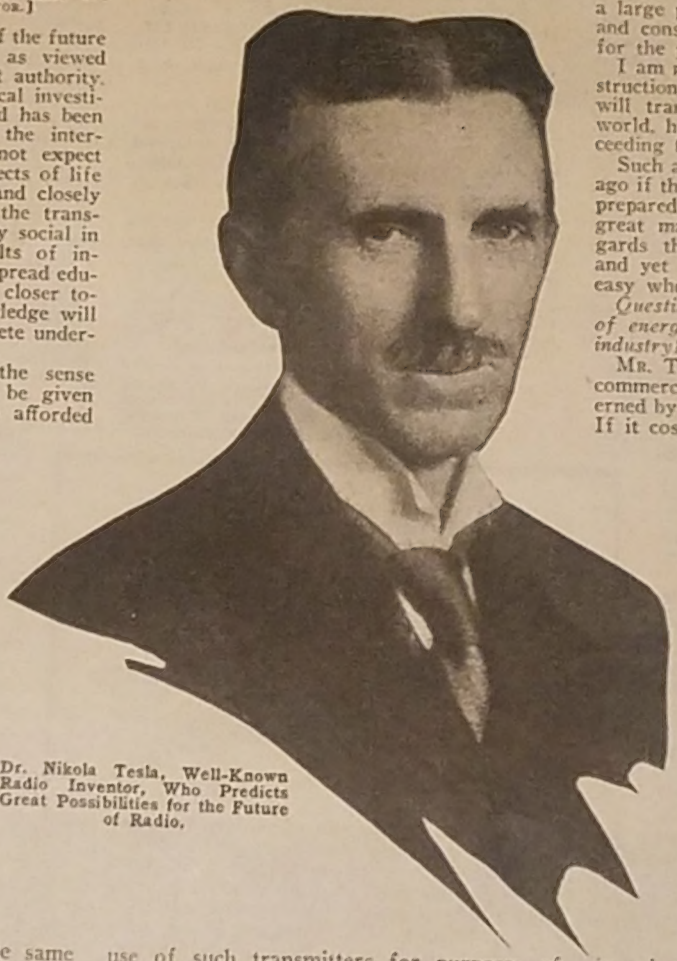
One of these inventions will enable us to condense the wireless transmitting apparatus to such an extent that the entire plant for carrying the human voice around the globe will be contained in a smaller space than that occupied by a little cottage. There will be no high towers.

In this connection I have made a discovery as interesting as it is important, which, when it is announced, will cause great surprise among engineers. This cannot be disclosed, now.

A number of other inventions relate to the control of the energy by delicate means, isolation of impulses, and their reception and recording at distance.

Question: What will be the effect of these inventions upon the wireless art?

MR. TESLA: I think that they will greatly facilitate wireless transmission in several ways. The transmitting apparatus will be very much cheaper and qualitatively superior by far to existing types. Especially in the use of such transmitters for purposes of broadcasting will great advantages be secured. The receivers will be much more responsive, too, and sharply differentiative. This means, of course, that more instruments can be operated simultaneously without interference and at greater distances.



Dr. Nikola Tesla, Well-Known Radio Inventor, Who Predicts Great Possibilities for the Future of Radio.

The compactness of the transmitter will greatly facilitate its installment, so much so, indeed, that I look confidently to the time when all leading newspapers and large institutions of business will possess equipment enabling them to communicate with any part of the world.

Newspapers, for instance, could maintain their own transmission plants, which could be used not merely for broadcasting news bulletins as an auxiliary service to their printed editions, but for gathering reports from their correspondents; and business concerns could have their own private systems by which they could have direct communication with their agents and customers everywhere.

Question: You have established the fact that electrical energy can be transmitted without wires—how soon will it be possible to carry on such transmission on an industrial scale?

MR. TESLA: I have been confident, ever since I gave the outline of my wireless system in scientific lectures delivered in 1893, that power could be transmitted without wires, and that ultimately we would establish plants for such transmission on an industrial scale. But it was not until 1899 that I obtained absolute experimental evidence that this could be done in a manner far more perfect than I had dreamed of before. Ever since that time I have devoted a large portion of my energy to the design and construction of the devices to be used for the purpose.

I am now prepared to undertake the construction of a wireless power plant which will transmit energy to any point in the world, however distant, with a loss not exceeding five per cent.

Such a plant would have been erected long ago if the profession (engineering) had been prepared for it. But, as a matter of fact, a great many engineers are in doubt as regards the possibility of this achievement, and yet it is as with everything else, very easy when you know how.

Question: How will wireless transmission of energy affect the present machinery of industry?

MR. TESLA: It must be remembered that commercial enterprises always will be governed by economic principles. To illustrate: If it costs less to propel an airship by fuel than it would if wireless energy were employed, then fuel will be used and wireless energy will be looked upon as a luxury.

The history of invention proves that new developments always take place along the lines of least resistance and that invariably time is given for the adjustment of existing conditions.

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(Continued on page 940)

A Huge Tesla Apparatus

A Coil With a Seven-foot Spark Gap

By Father Francois Magri, S. J.

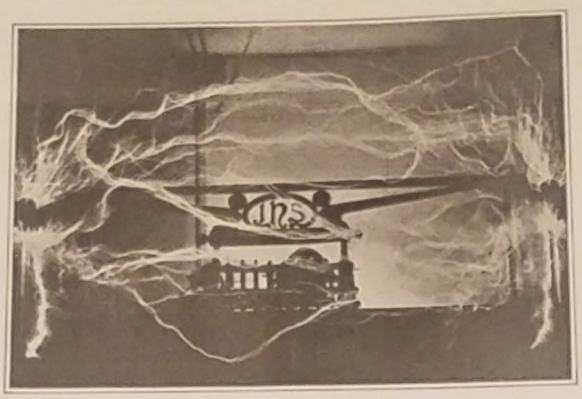
THE great Tesla apparatus of our physical laboratory, at the College of the Immaculate Conception, Montreal, was designed by my predecessor, Father Germain, and was constructed by his pupils.

The current of low frequency which energizes the Tesla coil proper, is furnished by a 7-kilowatt transformer, entirely immersed in insulating oil in a glass case, which measures 27 inches in length, and 17 inches in width and height. Its primary coil is connected to the city lighting circuit of 115 volts and 60 cycles, from which it takes a current of 60 amperes. The voltage of the secondary current exceeds 65,000 volts, as is proved by the length of the spark, which has the flame-like appearance shown in one of the photographs. This secondary current passes into the primary coil of the Tesla transformer, which is connected with a condenser of 144 Leyden jars. These jars are filled with and surrounded by salt water, which takes the place of the customary metallic coatings, and which is covered by a thin layer of oil to prevent evaporation and incrustation. A rotary interrupter, driven by an electric motor, is employed in order to increase the frequency.

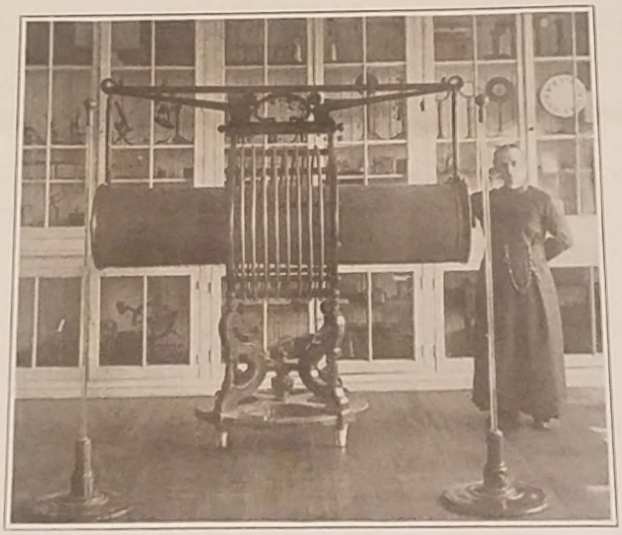
I have made important changes in the apparatus, entirely reconstructing the primary of the Tesla, and improving the insulation by mounting the wooden base on glass supports. The apparatus is more than 7 feet long. A cylindrical cage, 33 inches in diameter, composed of 12 longitudinal bars, 22 inches long, carries the primary coil, which consists of 8 turns of brass tubing, separated by intervals of 1½ inches. The diameter of the tube is ⅝-inch, and its total length is 74 feet. Its ends are connected with the condenser and the rotary interrupter. Above this coil is a bridge, from the ends of which the secondary coil is suspended inside the primary by means of two ebonite rods 19 inches long. The secondary coil is nearly 7 feet long and more than 17 inches in diameter. It is composed of more than 1,000 turns of fine, enameled copper wire, insulated by layers of tarred paper and cloth. The maximum sparking distance is 6 feet 8 inches usually, but it has exceeded 7 feet. The spark resembles a flash of lighting and, with its deviations, attains a total length of nearly 10 feet. It produces a sound like a thunder clap that startles persons in the street, 400 feet distant. Although the apparatus is not connected either with an antenna or with the earth, the sound of the discharge is heard very distinctly through the telephonic receiver at the wireless station of the Polytechnic School, a mile and a half away, this receiver also being disconnected from its antenna and the earth.

What, then, would be the result of connecting this powerful apparatus to earth and to our experimental antenna, consisting of three wires, each 700 feet long? The discharge would certainly produce a potential difference of at least five million volts, but we have no apparatus with which this theoretical deduction can be verified.

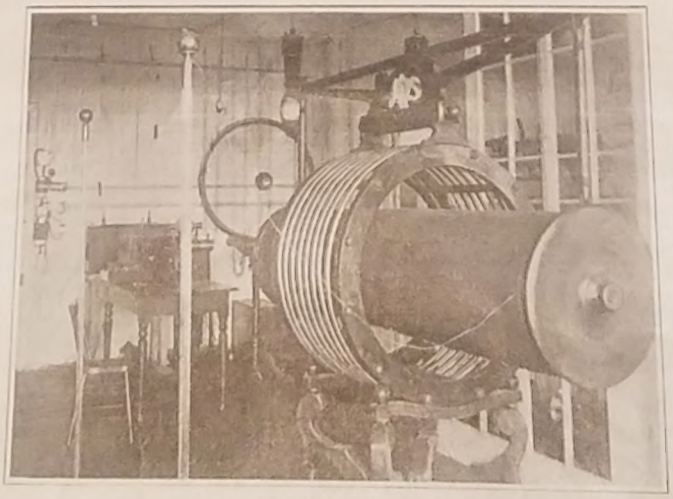
The discharge of the primary coil alone produces a deafening noise. This coil, by induction alone, heats to incandescence a 50-volt lamp, inserted in a little coil of three turns at a distance of 3½ feet. A 25-volt lamp glows brightly at the same distance, and a 12-volt lamp is heated to whiteness at a distance of 5¼ feet. When the terminals of the primary are connected by a coarse iron wire 8 feet long, the wire is almost instantly heated to incandescence and fused. Sixteen 115-volt lamps glow white when they are connected in series between the terminals of the primary.



Discharging across a seven-foot gap.



Giant Tesla coil capable of giving a seven-foot spark.



View of the primary and movable electrodes.

A Monumental Bibliography of Science.—After a lapse of 12 years a new volume has appeared in the Catalogue of Scientific Papers, published by the Royal Society of London, viz., Vol. XIII, beginning the Fourth Series, which is to embrace all scientific papers published during the period 1884-1900, and winds up the work. This volume contains 11,551 entries of titles of papers by 2,001 authors whose names begin with A, and 51,720 entries of papers by 6,928 authors whose names begin with B; in all, 63,271 titles. In the preparation of the catalogue 1,555 serials were examined. The Royal Society Catalogue grew out of a suggestion made by Dr. Joseph Henry of the Smithsonian Institution, to the British Association in 1855, and the first volume appeared in 1867. The volumes of the first series include the literature of the years 1800-1863; those of the second, the literature of 1864-1873; and those of the third, that of 1874-1883. The fourth series will round out the century. Supplementing the volumes of the main work, in which titles of papers are arranged under authors' names, the latter being in alphabetical order in each series, a series of index-volumes is in course of publication, in which the periodical scientific literature of the whole century is grouped under appropriate subject headings. Three index volumes have appeared, viz., Pure Mathematics, Mechanics, and Physics (in two parts). There will be seventeen of these index volumes. Finally, the scientific literature since 1900 (including titles of books as well as of articles in periodicals) has been catalogued regularly in the seventeen annual volumes of the International Catalogue of Scientific Literature, which is published by the Royal Society on behalf of an international council.

The Psychology of Catching in Baseball

By Arthur Macdonald

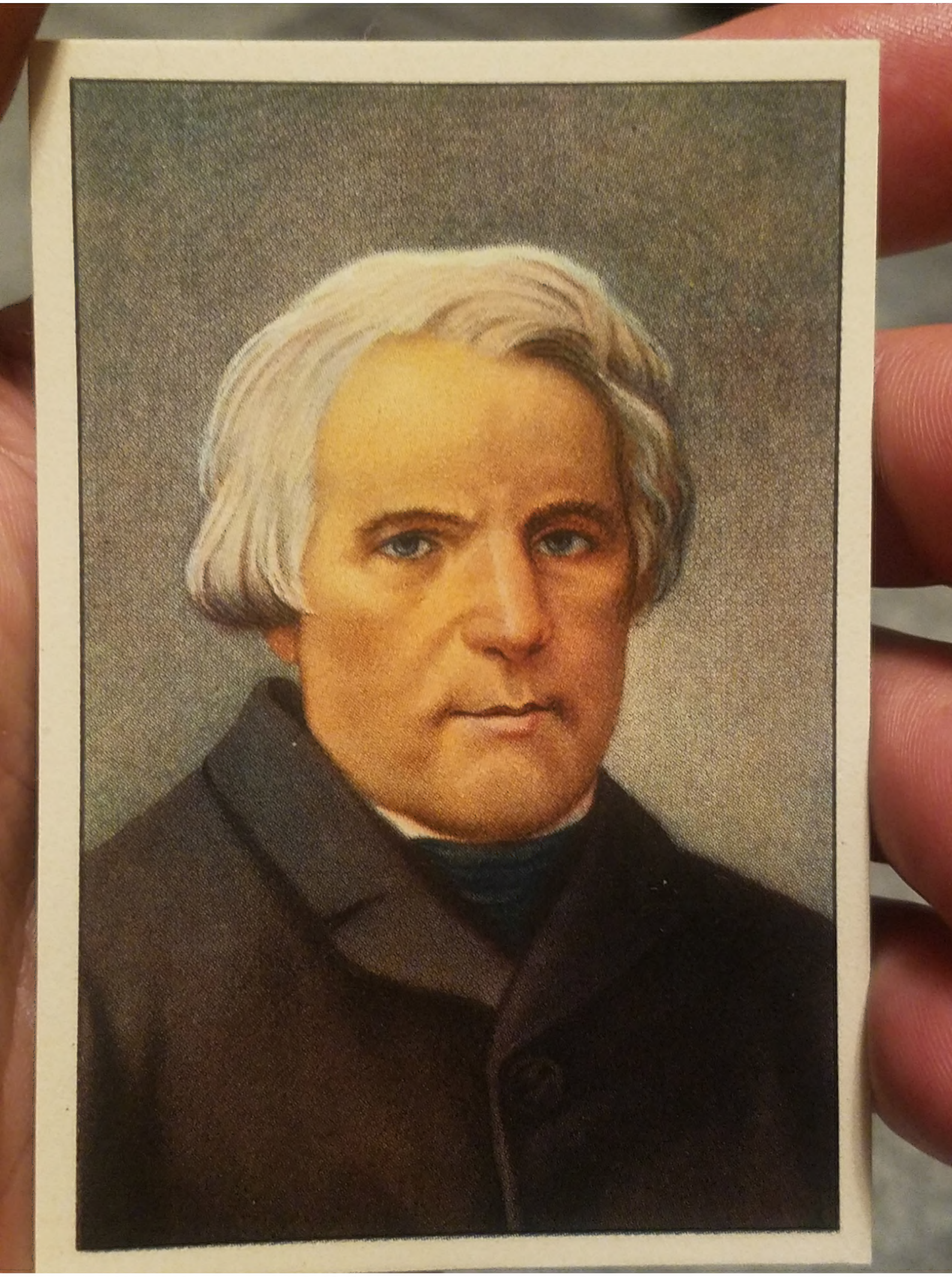
SPECIALIZATION has developed a tribe of catchers who are clumsy on their feet, usually weak at the bat, poor base runners, and of very little value when sent to other positions. Yet the catcher has a most important position, as director and transmitter of signals. Good fielders and hard hitters there are who are not quick-witted, but never a catcher, who is the first to see signs of weakness in the pitcher, and sends word to the bench for another pitcher to warm up. Three years' experience with a major league is regarded as necessary to make a catcher competent. Only a few continue long enough to have such experience.

Good catchers say that when they hear the ball touch the bat their hands instantly fly toward the ball, no matter where it glances off the bat. Some after losing sight of a fly in the sun have the ability to reach it nevertheless.

Sometimes catchers are unjustly blamed for not putting a runner out who gets a big lead off the pitcher (who is really at fault). Here not only a good throw will fail, but it is often useless to throw at all.

Good Catchers Make Many Unexpected Throws.—The catcher must throw from an unnatural position, and with a jerky motion of the arm. Archer threw with a snap of the arm while standing flat-footed and put many out on first base.

The catcher signals second baseman that he is going to throw the next pitched ball to him; the pitcher delivers it a little to one side, so that it can be handled easily; the shortstop knows the next ball will not be hit, and so can back up second base. This unexpected throw often puts the runner out on second. A similar play is when the runners move up every time the ball is pitched. If those on second and third both get well off the bags, the catcher again signals the pitcher to waste a ball, and makes as if he were going to throw to third, but instead, throws quickly to second and retires the runner there. Or makes as if he were going to throw to second, but instead, throws just beyond the pitcher when the baseman starts for second, and he, without stopping, runs up, catches the ball and sends it home to retire the man seeking to score.—Abstracted from *American Physical Education Review.*



41. Heinrich Ruhmkorff (1803-1877)

Constructeur d'instruments de physique. Allemand d'origine, il vécut et travailla surtout à Paris. Il construisit des instruments électro-magnétiques, des galvanomètres, des appareils d'induction exécutés avec une perfection qui lui gagna tous les suffrages. En 1851, il imagina de produire des courants d'induction dans une bobine de grandes dimensions et à deux fils. Cette belle invention, qui le rendit bientôt célèbre, fut féconde en résultats pratiques. La **bobine de Ruhmkorff** est encore d'un usage courant à l'heure actuelle; elle est notamment employée pour la production des rayons X, dans la télégraphie sans fil, etc.

Heinrich Ruhmkorff

Bouwer van natuurkundige toestellen. Duitscher van oorsprong, woonde en werkte hij vooral te Parijs. Hij maakte electromagnetische toestellen, galvanometers, inductieapparaten voltooid met een onwederlegbare volmaaktheid. In 1851 kwam hij er toe inductiestroomen voort te brengen in een klos van groote afmetingen met twee draden. Die schoone uitvinding, die hem weldra beroemd maakte, gaf talrijke practische uitslagen. De **klos van Ruhmkorff** wordt tegenwoordig nog algemeen gebruikt; hij wordt namelijk gebezigd voor 't voortbrengen der X stralen, voor de draadlooze telegrafie, enz.

War of the Future as It Will Be Conducted From the Viewpoint of Dr. Tesla. Machines of Destruction More Terrible Than Anything Yet Dreamed Of By the Master Minds Behind the "World War" Armies and Navies, Will Sail Under the Ocean and Thru the Skies—With No Living Soul Aboard. According to Dr. Tesla These Death-Dealing Monsters of the Sea and Air Will Be Controlled and Directed From Distant Stations Hundreds or Even Thousands of Miles Away By Radio Waves of the Proper Sequence and Frequency. The Tower-like Structures Shown in the Accompanying Picture are Transmitting Radio-Electric Power for Operating and Controlling the Sea and Air Defense Craft. The Giant Craft Drops Its Three Aerial Machines Passes Over an Enemy City, the Proper Radio Control Wave Is Flashed Out and the Giant Craft Drops Its Bombs, Destroying Buildings and People as Well. Man Will Be the Master Mind Behind the Future War, But Machines Only Will Be Mortal Combat. It Will Be a Veritable War of "Science."

An Interview With Nikola Tesla

By H. WINFIELD SECOR

AT the present day when many momentous problems in science and international politics are being weighed in the balance of logic and reason, it is a very opportune time, it seems, to listen to the views and ideas entertained on some of these problems by such a famous engineer and scientist as Dr. Nikola Tesla. The interviewer wended his way across Bryant Park in the shadow of the great Astor Library and ascended to the 20th floor of an adjoining skyscraper, where Dr. Tesla has his offices and laboratory. Having made known my mission, I asked Dr. Tesla the following questions:

The Disarmament Conference

Q. Do you believe that the Disarmament Conference now being held at Washington will do much good, especially with respect to prevention of war?

A. The extraordinary proposal of Secretary Hughes has produced a favorable impression thruout the world and the remarkable readiness with which it was taken up by the foreign governments is an auspicious beginning. Some agreements as to naval expenditures and status of the Powers in the Pacific have already materialized and that other results of value will follow there can be no doubt. But it is equally evident that they will consist merely of economic measures, which can have only a negligible influence as preventatives of war.

The primary object of the Conference is the reduction of armaments. As the safety of any country depends not on the absolute, but relative, military strength a proportionate reduction of the force and equipment suggests itself naturally as a means of lessening the cost of upkeep. This is a very old idea in the practical application of which insuperable difficulties have been encountered heretofore for want of proper standard of reference. The requirements are different in each individual case and an attempt to make the reduction on the basis of population, area, resources, industry, commerce or any other national asset, would be manifestly futile. Moreover, participation by every nation is essential to the thoro execution of such a plan, and to arrive at an adjustment satisfactory to all would be next to impossible. All that can be accomplished at present is some equitable treaty between the few leading countries for minimizing the burdens of war, which is highly desirable for economic reasons but leaves the main problem unsolved. The idea that armed conflicts between nations can be prevented by written covenants involves a scientific fallacy. It is an attempt to put effect before the cause. Experience must precede the formulation of laws. Universal peace may be eventually brought about by civilizing forces and agents and international conferences will then only serve the purpose of giving clearer expression to a common desire. Nevertheless, the conclusions reached at Washington may prove of tremendous consequence in time to come, especially for this country which, until lately, has adhered to its traditional policy of isolation.

On general principles three courses are open to the United States. One is to continue arming and maintain an overwhelming superiority over other nations. The inexhaustible wealth of this country would easily enable it to keep up the pace and if safety is placed above every other consideration this should be done. The carrying out of the program would call for vast outlays but under the conditions existing American military supremacy might, perhaps, be the best means of insuring general prosperity and welfare. The second is to advocate complete disarmament insofar as the enforcement of law and order would permit. In that case this country would still be safe, as its resources would enable it to prepare for war quicker than any foe. The third is to enter an agreement with other powers, limiting the armaments, which would virtually mean an alliance involving more or less hazard and peril.

As regards the abolishment of war, the measures adopted by the Conference to this end will be as futile as all the previous ones. Opinions on this subject are divided. In the view of some, war is the greatest curse; others think it is a psychological necessity and beneficial—like a storm which clears the atmosphere. There is a perpetual conflict going on between nations as well as individuals. Ordinarily it is merely a competitive struggle, occasionally it becomes a deadly strife. This is primarily due to imperfect mutual understanding and the basic physical cause is the immense extent of the terrestrial globe. The most effective means towards insuring universal harmony and peace is, accordingly the annihilation of distance which must be brought about in three distinct respects: (1) dissemination of intelligence; (2) transmission of energy, and (3) transport of bodies and materials. All this can be done thru the development of the wireless art. As the first step I proposed twenty years ago my World-System which would leave all the present means intact and enable instantaneous transmission from one to any other point of the globe, of signals, speech, pictures and characters of every description. I have made important improvements since and am almost assured that a number of comparatively very small and compact plants, with a telephonic range of twelve thousand miles and devoid of high towers, will be put in operation in various countries. Of immeasurably greater consequence, however, will be the wireless transmission of energy, which can be successfully effected by the use of the same underlying principles and will make cheap motive power for all purposes available everywhere. Then it will be possible to propel flying machines at great speed without fuel and thus space will be annihilated and the impediments to contact and mutual understanding removed.

NIKOLA TESLA has no doubt one of the greatest intellects of his time. Our readers will be pleased to peruse his latest ideas concerning world matters of interest to all of us. We have stated in our columns before that Dr. Tesla is at least 100 years ahead of our times. Many of his prophecies have come true in the past, and we believe that the words which he addresses to the world thru SCIENCE AND INVENTION will be listened to attentively by all.
—EDITOR.

Future Wars

Q. What are your views on science in respect to future wars?

A. Discovery and invention ever tend to intensify the forces and agents for attack and defense. The wars of the future will have no semblance to those waged up to now. They will cause less physical suffering but will be all the more terrible. The countries engaged in the conflict will not send out armies, fleets, or aerial squadrons to meet in battle, but crewless vessels will be launched from one to the other with enormous speed and at distances of thousands of miles. Such apparatus does not exist but could be speedily constructed and in an article on "Telautomatics" which appeared in the ELECTRICAL EXPERIMENTER (former name of SCIENCE AND INVENTION) of October, 1919, I have endeavored to convey an idea of the same. These infernal engines will drop quantities of poisonous gases and other destructive chemicals on any city or place, the geographical position of which is accurately known. Battleships, guns, torpedoes, submarines and even manned flying machines will become of trifling importance and there will be no need for admirals, generals, or commanders of forces, as all the work will be done by electricians, engineers and mechanics.

International agreements will not stop war, for the simple reason that they will be ignored the moment the life of the nation is at stake. To preserve itself it will sacrifice everything else. That is why Germany violated the neutrality of Belgium and why Italy deserted her allies. Before universal peace can be attained the whole human race must be changed for the better, thru closer contact and cultivation of a higher ideal, which will gradually supplant that of patriotism.

Is There Vegetation and Life on the Moon?

Q. Do you believe that there is vegetation and life on the moon, which we have always been taught possesses no atmosphere capable of supporting such?

A. I have read with great interest the announcements of Professor Pickering, as well as some adverse comments on the same. Personally I am inclined to place greater faith in the statements of a painstaking specialist than in the opinions of those who have not studied the subject, however competent they might be otherwise. The observations of this astronomer, if confirmed, will be of great importance, not only to science, but because of the psychological effect on human beings. I have always thought that any evidences of life on other planets would be of incalculable benefit to our world, and this is why I have devoted much of my energies to interplanetary communication ever since I received, in 1899, the singular disturbances that, according to all experimental evidence, emanated from Mars.

Future of Electrical Engineers

Q. What are the chances today and in the immediate future for electrical and radio engineers?

A. As regards the application of electricity, although the development of late

(*Continued on page* 957)

MR. TESLA: I think that they will greatly facilitate wireless transmission in several ways. The transmitting apparatus will be very much cheaper and qualitatively superior by far to existing types. Especially in the

Dr. Nikola Tesla, Well-Known Radio Inventor, Who Predicts Great Possibilities for the Future of Radio.

represented [illegible] this task in actual service. It comprises a small motor the axis of which carries a hard rubber disc inserted in a brass ring; a readily exchangeable helium tube inserted into the latter is at one of its terminals connected with the brass ring and at the other with the motor body. The hard rubber disc rotates within another a stationary brass ring supplying current to the helium tube. When, as shown, two incandescent tubes are arranged on the rotating disc, the vibratory condition can be observed permanently in two circles. A uniformly lighting disc, as in Fig. 9, tells the official in charge of the service that the vibration circuit in question is traversed by currents of constant amplitude. The apparatus is especially valuable in wireless telephony for ascertaining the influence of spoken words on the course of vibrations in the radiating system. Fig. 10 shows records of the spoken vowels "*a*" (as in "father") and "*o*" respectively, as obtained by means of the vibration tester.

A Swiss C.W. Transmitting Station

(*Continued from page* 831)

supplied from a power station into direct current, while the other, viz. a gasoline engine designed to be coupled to the direct current, feeds an alternate current converter supplying the 500-cycle alternate current required for operating the sender.

The sender is a standard Telefunken 1-K.W. tube set, deriving its anode tension from the alternating current, previously transformed to 3,000 volts and rectified. The alternating current, moreover, serves to heat the filaments of the sending tubes. The transmitter, with a range of wavelengths from 400 to 5,500 meters, will bridge distances of 1,000 to 1,500 kms., the key being either operated by hand or by means of a Siemens high-speed telegraph, through distant control from five different Swiss cities. The key-relay will readily deal with 120 words per minute. Additional apparatus for wireless telephony has been provided.

The corresponding receiver plant at Dübendorf comprises two separate receivers which are either used in connection with a vertical or with a loop antenna. Morse recorders have been provided.

It is hoped to use this station not only for direct radio communication with Berlin, Paris, Rome, Vienna and Prague, but for an economic broadcasting service on the lines of the one arranged in Germany.

Tremendous Possibilities of Radio

(*Continued from page* 833)

apparatus, which he can carry in his kit with ease, and before he departs arranges with the power plant owners for service; then when he reaches his destination, no matter how wild and inaccessible it may be, he can be supplied with all the light and power which he may need.

I am looking with the greatest confidence to an application of the wireless principle for purposes of lighting on a vast scale, but this will not interfere with the lighting of cities and populated districts from central plants.

The new art will be of small effect, in itself, on the cost of production. There is an idea in the popular mind that wireless power will be had for nothing, but this is

far from being so. The primary energy has to be provided, either from a waterfall or by burning fuel.

To sum up, I have always visualized the wireless art as being applied to fields not supplied by present systems. These will endure for a long time, until conditions economically demand the substitution of a new system.

Question: When wireless transmission of energy becomes an industrial fact, will not the larger part of the present system of fuel transportation become obsolete? Will not practically all power then be produced close to, or in, the mine and oil fields and at water power stations?

Mr. Tesla: The engineering world at present is developing the so-called super-power system, which I have advocated for twenty years. It will be the means of furnishing energy more economically and over greatly increased areas. Wireless transmission would not seriously interfere with it.

Of course, there are innumerable places where power transmitted without wires would be of relatively greater value and in commercial enterprises this consideration would govern the installation of receivers.

As to the present system of hauling fuel to great distances: Engineers are centering their efforts on reduction of this waste, that being precisely one of the objects of the super-power system. But, while plants operating with wires must be favorably placed, a wireless plant can be located without reference to natural advantages. This is important.

There is a strong tendency now to erect power plants close to the coal and oil fields and the sources of water supply. Industry will be greatly benefited when this idea is carried out on an extensive scale.

Question: Will not wireless transmission of energy result in time in the moving of practically all means of transportation with electrical energy from central power stations?

Mr. Tesla: No, I do not expect that such will be the case, for the transportation systems now used present certain important practical advantages which cannot be disregarded.

Question: Will not automobiles, for instance, be operated merely by the operative "cutting in" on electrical energy supplied by wireless from power stations?

Mr. Tesla: I fear we shall not live to see the wireless system in general use for this purpose. It is difficult to propel an automobile by the new method for reasons with which experts are familiar. Success can be much more easily achieved in the case of airships.

In time to come it is possible that some form of automobile may be perfected that will enable this propulsion of such vehicles to be effected by power drawn from the ambient medium.

Question: Will the transmission of large amounts of electrical energy by wireless constitute any sort of menace to life and property?

Mr. Tesla: None whatever. We live on a globe which is charged to a pressure of two billion volts and we do not feel it at all, although it is possible that we may be affected by this immense pressure in some way or other. Lightning discharges usually occur under a tension of 1,500,000,000 volts and yet the powerful oscillations set up are insensible. Wireless transmission will be effected by electric currents of much smaller force than this. Far from being a menace, the new art will enhance in innumerable ways the safety of life and property.

Question: Getting back to the wireless transmission of sound, will it be possible to develop voice detectors that, at a distance, say, of four or five hundred feet, will amplify sounds so they can be heard plainly?

Mr. Tesla: Of course it will. The human ear, though an organ much inferior to

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the eye, is wonderful just the same. It may be of interest for me to state that at a certain period in my life, when I suffered from hyper-excitation of the nerves, I could hear distinctly a fly walking on a table at a distance of several feet, and when he alighted I heard a strong thud.

In my experiments at my wireless plant at Colorado Springs in 1899 I could easily hear with the unaided ear thunder claps at a distance of 550 miles, although my assistants could not hear beyond 150 miles.

I believe it possible to perceive the sound of a strong explosion at a distance of 12,000 miles. If this theory is correct, it explains the extraordinary behavior of many persons afflicted with nervous diseases.

There are amplifiers of various kinds by which a sound can be multiplied a billionfold. There is virtually no limit in this direction.

Question: In one of your articles you declared you believed it possible to precipitate rainfall by means of wireless energy. Is there a probability of this being an early materialization?

MR. TESLA: That is an idea on which I have labored since 1892, when I accidently observed that a stroke of lightning caused a copious downpour. Twenty years ago I had advanced so far in the design of the means for accomplishing this purpose that I made every effort to carry out the idea on a large scale.

But I found my plans were received with skepticism. We undoubtedly will accomplish this wonder some day and then will come the lords and masters of life on this planet. We will be able, then, to obtain any amount of power almost without effort and produce lakes and rivers where all was barren before. All the work will be done by the sun; man will merely press the button.

Hitherto the interview had concerned itself solely with the utilitarian aspects of the wireless principle. At this point the following question was propounded:

The development of water power and of the wireless transmission of electrical energy produced by water power would indicate that in the far distant day when coal and oil are exhausted those countries having large quantities of water power will become exporters of electrical energy to less fortunately situated countries. Does not this mean new political adjustments and division? Or will wireless telephony, hastening the day of world peace and international progress, long before that time prepare mankind, through increased intercourse and education, for the cooperative use of natural resources?

The scientist's reply was a *proper finale.*

I have always considered the wireless art the greatest advance of all ages. That is why it has been the chief object of attainment in my life.

We will never overcome international friction and wars by pacts and agreements, however solemn, nor will we by this means abolish the barriers that separate the nations from one another and are an impediment to general progress. There is only one way of achieving this great end and that is by annihilating distance. The wireless art will accomplish this in every aspect.

Of particular importance as means for insuring peaceful relations between nations and communities will be wireless telephony and picture transmission. The latter is crude and imperfect, but carries the convincing power of a record. The time is not distant when we will have wireless television, which is immensely more difficult to accomplish and correspondingly far reaching in its effects on human life. No such apparatus is in existence, now, but the preliminary steps necessary to the successful solution of this great problem already have been made.

The combined use of the wireless telephone and the apparatus for television will put human beings in intimate aural and visual contact though thousands of miles may separate them. So to speak, a man will be able

to lean out of his window in New York and talk to his "neighbor," similarly placed in Paris.

The consequences of such an achievement are inestimable when considered in relation to our social and political progress.

A New Type of High Power Vacuum Tube

(*Continued from page 853*)

up to very large sizes. Some of these are about 1" in width, and capable of successfully conducting a current of 150 to 200 amperes.

In the general use to which these seals are put there is no necessity for having the glass surround the circumference of the copper disc and the necessity for sharpening the edge is obviated by allowing the glass to adhere to the flat portion of the disc only, care being taken to prevent its flowing around the edge. It is necessary to have a ring of glass on both sides of the seal in order to equalize the bending stresses which would otherwise tend to break the glass and copper away from each other.

The third type of seal and the most important in connection with the present problem is the tube seal shown in Fig. 3. This furnishes the means of joining metal and glass tubes end to end and is used in the water-cooled tube to attach the anode to the glass cylinder which serves to insulate the other tube elements. As in the case of the disc seal, it can be made either with the edge of the metal not in contact with the glass, as shown at A, or with the metal sharpened to a fine edge which is in contact with the glass. The glass may be situated either inside or outside of the metal, see B and C.

The first thermionic tubes in which these seals were embodied were made of copper and were designed to operate at 10,000 volts and to give about 5 K.W. output.

A photograph of the inside of one of these tubes is shown in Fig. 4.

The anode consists of a copper tube 1.5" in diameter and 7.5" long. A copper disc is welded to one end forming a vacuum-tight joint. The other end which is turned down to a knife edge is fused directly to a glass tube.

The filament grid assembly consists of two lavite discs D and E, spaced 5" apart by a seamless steel tube. The grid F is made in the form of a helix, and is held in position by allowing the ends of the longitudinal wires, to which the turns of the helix are welded, to pass through holes in the lavite blocks D and E. The filament G is mounted between hooks fastened to the lavite blocks and is kept taut by the springs H. The grid lead is shown at J, and the filament leads at K K. In this tube platinum seals are used for the lead wires. The use of the springs H make it necessary to supply the filament with current from the opposite end of the assembly and this is done by passing the current through the steel support tube and returning it through a lead passing through this tube and insulated from it by a quartz tube.

The whole assembly is carried by two supports B B. These supports are welded to a corrugated nickel collar A which grips the glass stem C.

The pumping of these tubes at first presented considerable difficulty, chiefly on account of the large amount of occluded gas contained by the metal parts. This caused the time of pumping of the tube to be very

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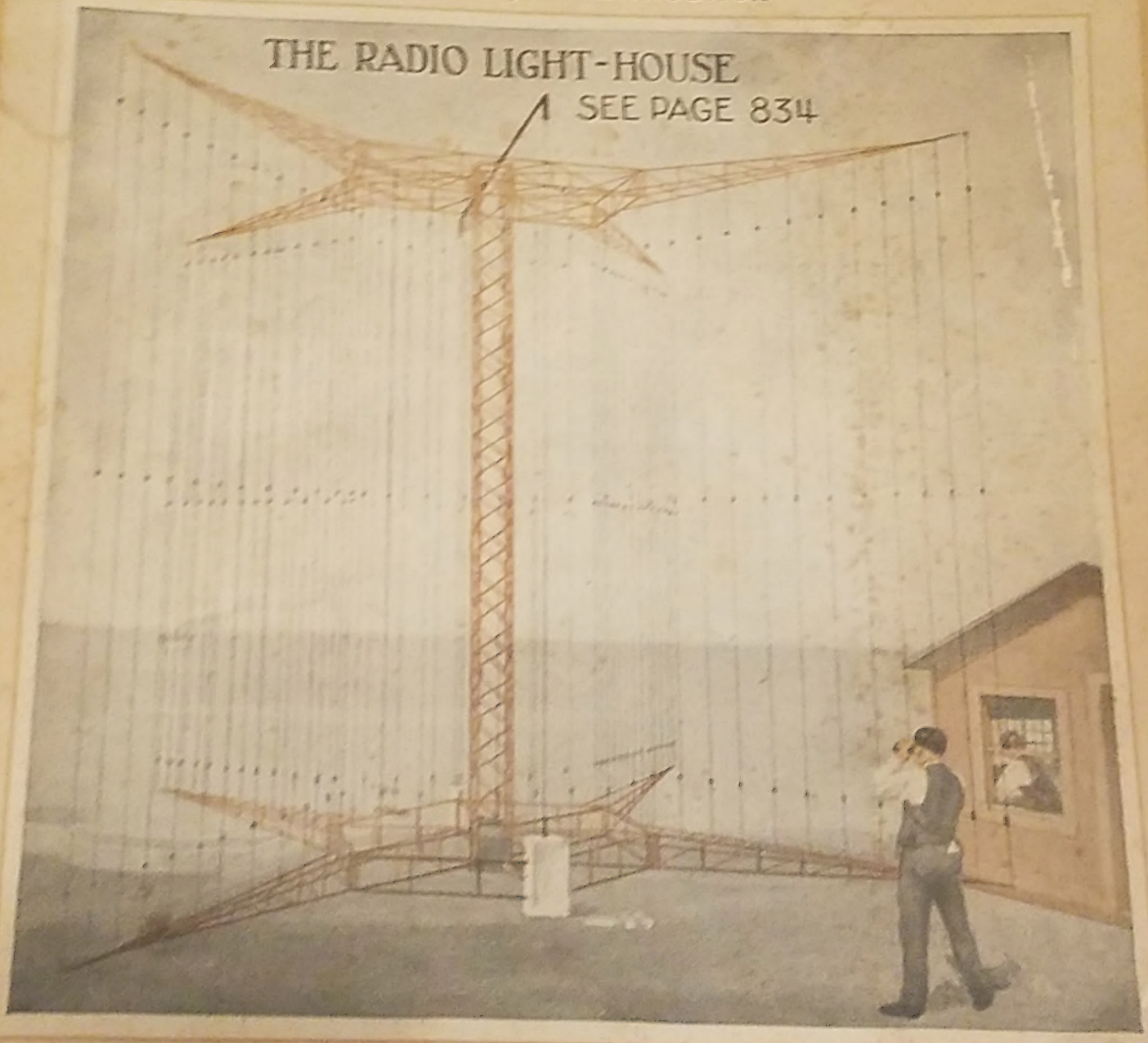

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